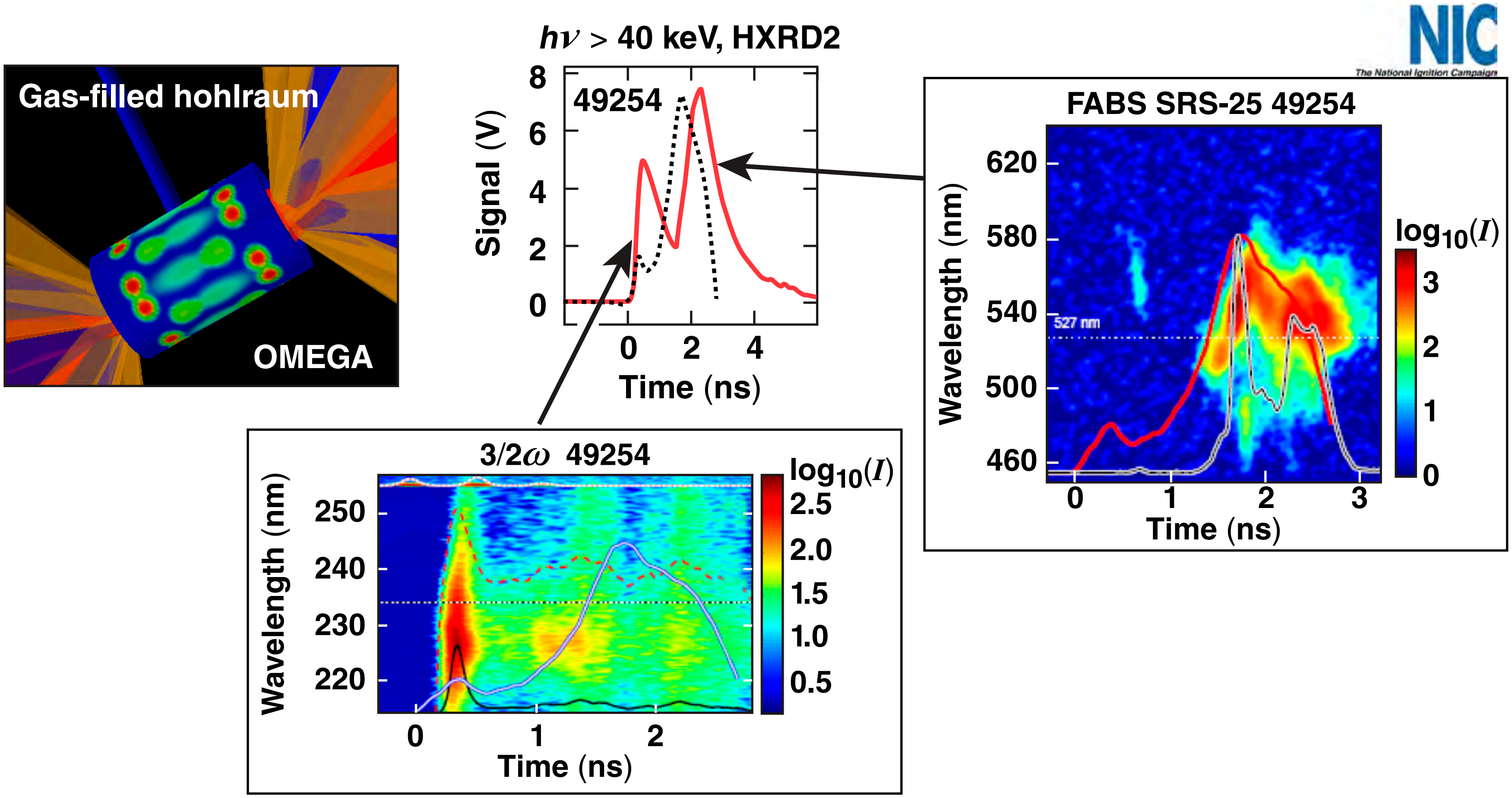
Hohlraum Hot-Electron Production



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Summary

Two bursts of hard x rays generated by hot electrons are observed from gas-filled hohlraums on OMEGA

- The coupling of laser energy into hot electrons was investigated with the hard-x-ray diagnostic (HXRD) for Au hohlraums using the following drive conditions:
  - 40 beams with three-cone geometry
  - elliptical phase plates
  - shaped laser pulse (PS26)
- The first x-ray pulse (T_{hot} ~ 75 keV) scales with the foot intensity and appears to be generated by the two-plasmon-decay ($2\omega_{pe}$) instability in the exploding laser entrance hole (LEH) window.
- The fraction of laser energy coupled to hot electrons f_{hot} scales with the initial electron density ($0 < n_e < 0.1\ n_{cr}$) of the fully ionized hohlraum gas fill.
- The second x-ray pulse (T_{hot} ~ 20 keV) coincides with SRS during the main drive.
- Mid-*Z* dopants in the gas fill reduce hard-x-ray production of the second pulse.

NIC experiments → hot-electron preheat of NIF ignition target

1. Gas-filled hohlraums can meet NIF requirements for the main drive.
2. Foot intensity can be adjusted to meet NIF requirements for the first x-ray pulse.

E16296

*see 2-D simulations in next talk, N. B. Meezan (NO6.00005).

Collaborators

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Hard-x-ray data from 32 NIC hohlraum energetics and symmetry shots were analyzed in this study

Initial n_e of ionized gas fill (0.9 atm)

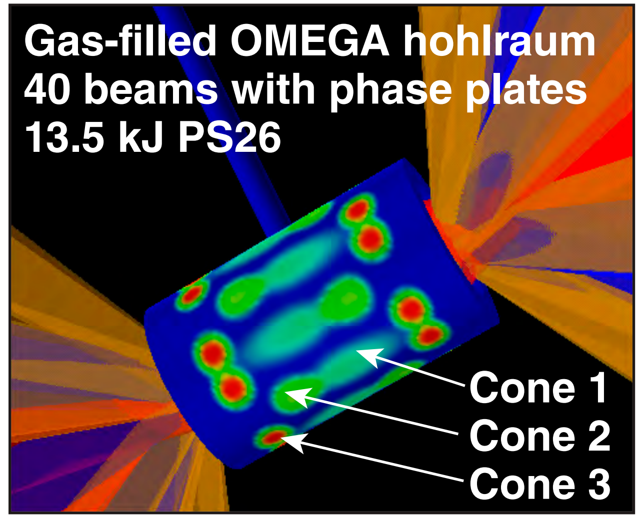
CH_4 → $n_e = 0.02\ n_{cr}$
$CH_4 + C_5H_{12}$ → $n_e = 0.04\ n_{cr}$
C_5H_{12} → $n_e = 0.1\ n_{cr}$

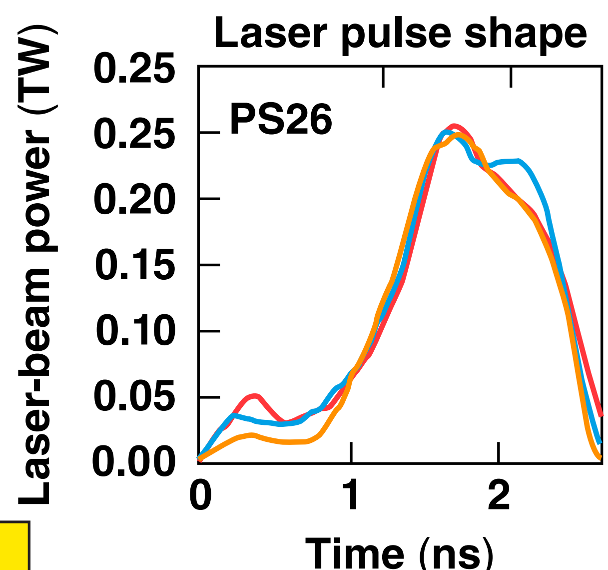
Thin-walled, scale-1 hohlraum
Au thickness = 2 to 5 μm
i.d. = 1.6 mm
L = 2.3 mm
LEH = 1.07 to 1.2 mm
Polyimide window 0.6-μm thick

- Some hohlraums had implosion capsules
- Some gas fills had Ne and Kr dopants (3% pp)

Primary diagnostics
HXRD*, DANTE
3/2ω spectrometer
FABS and NBI

Peak overlapped intensity on LEH during foot was varied from 0.6 to 1.2 $\times\ 10^{15}$ W/cm^2.





*C. Stoeckl *et al.*, Rev. Sci. Instrum. 72, 1197 (2001).

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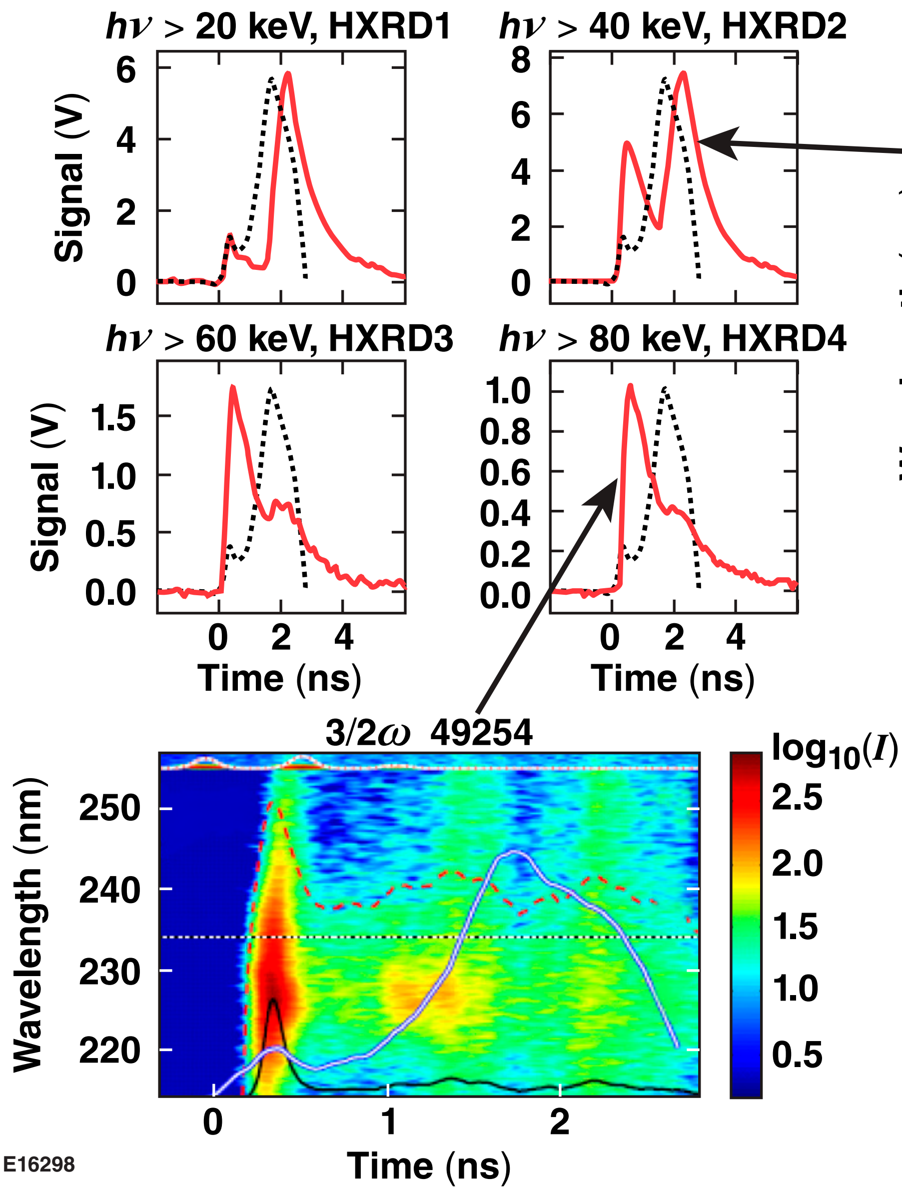
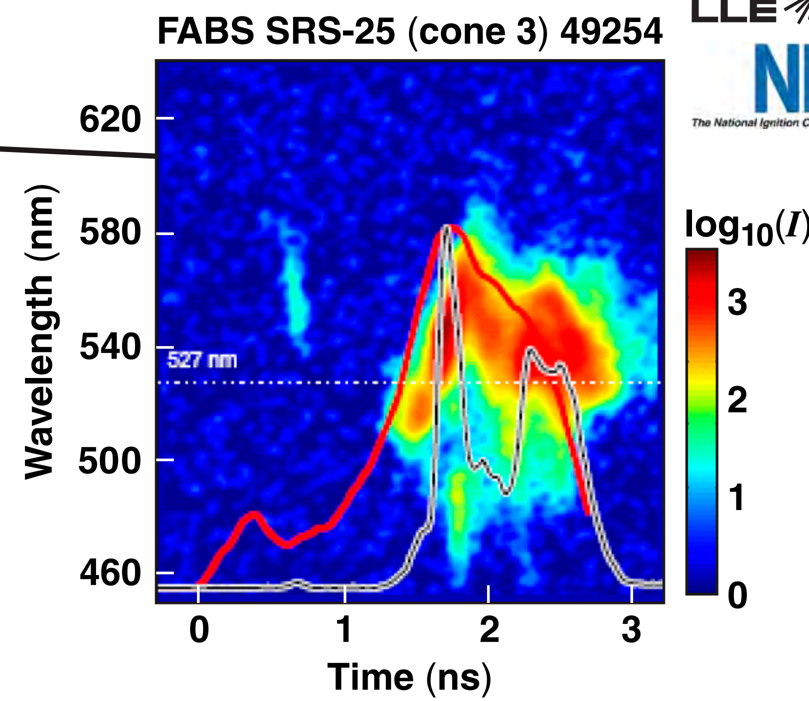
Hot electrons appear to be produced by the $2\omega_{pe}$ instability for the first x-ray pulse and by SRS for the second pulse





Only a single burst of x rays is observed from vacuum hohlraums because they do not have an LEH window

Data for C_5H_{12} fill (n_e ~ 0.1 n_{cr}) with I_{foot} =1.2 × 10^{15} W/cm^2

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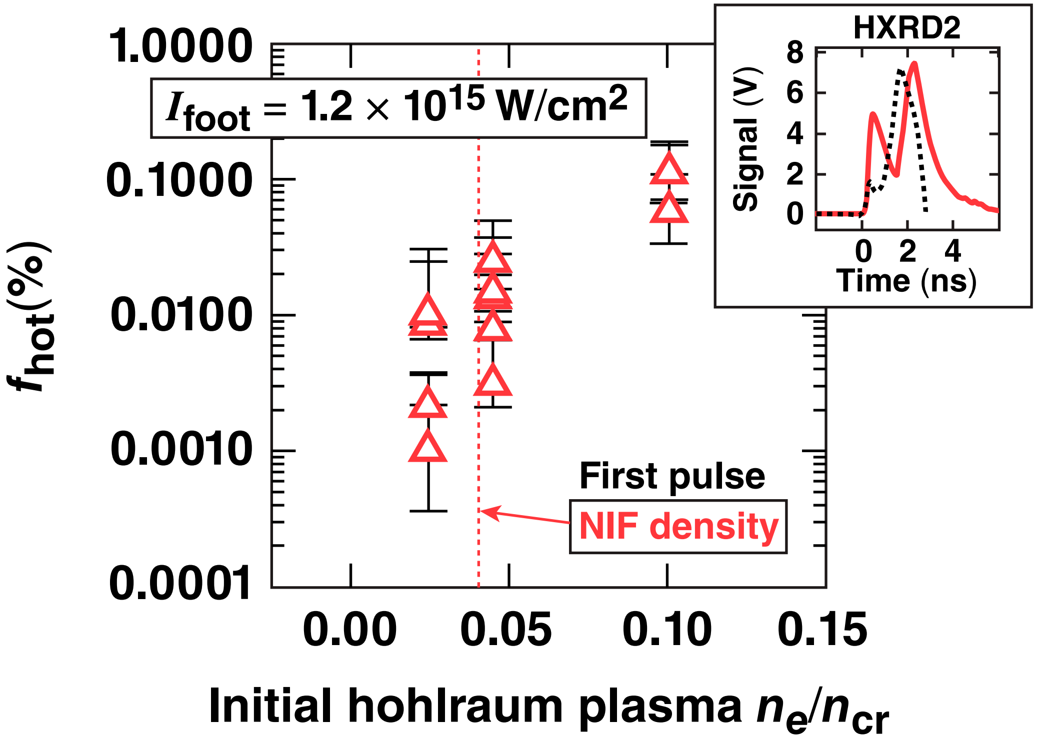
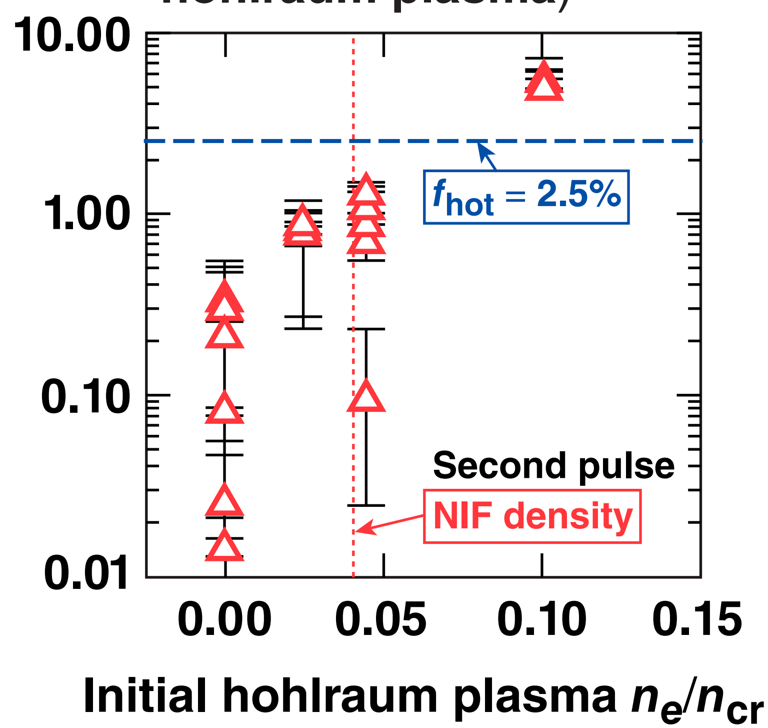
f_{hot} scales with the initial electron density (n_e) of the ionized gas fill

First x-ray pulse
(from LEH window plasma)



Second x-ray pulse
(from main drive hohlraum plasma)



NIF requirement for main drive of indirect-drive-ignition design
$f_{hot} \leq 2.5\%$ for $T_{hot} = 30$ keV

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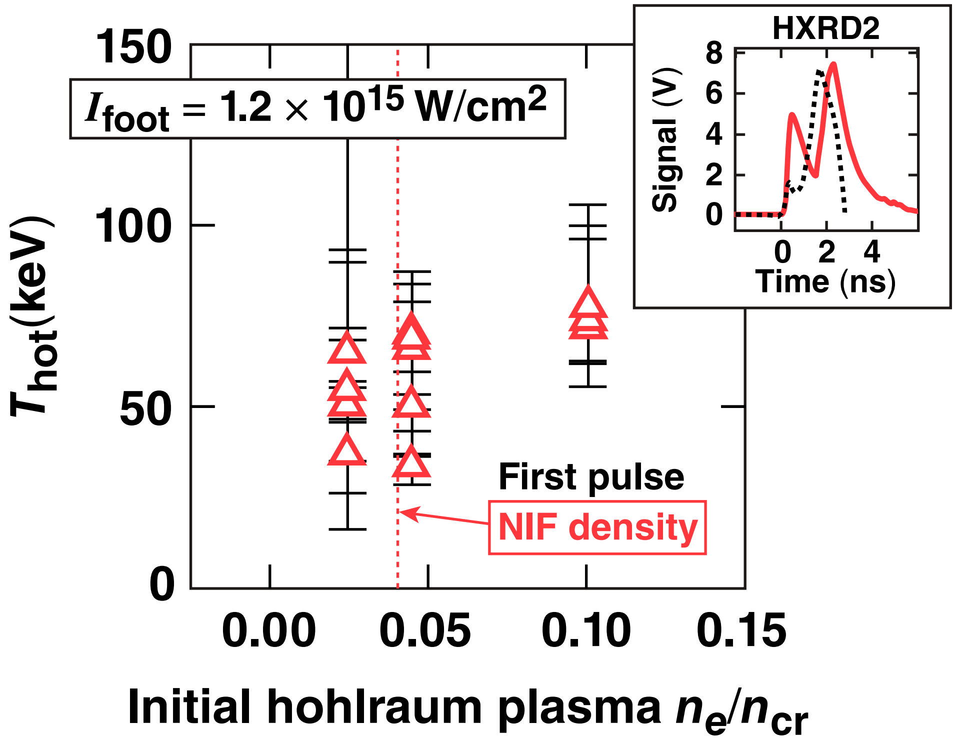
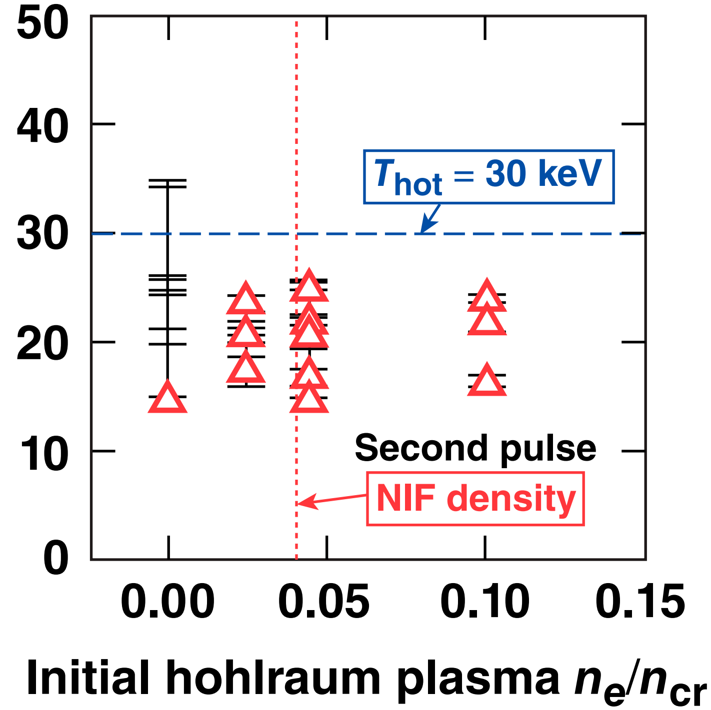
T_{hot} is higher for the first x-ray pulse (~75 keV) than it is for the second one (~20 keV)





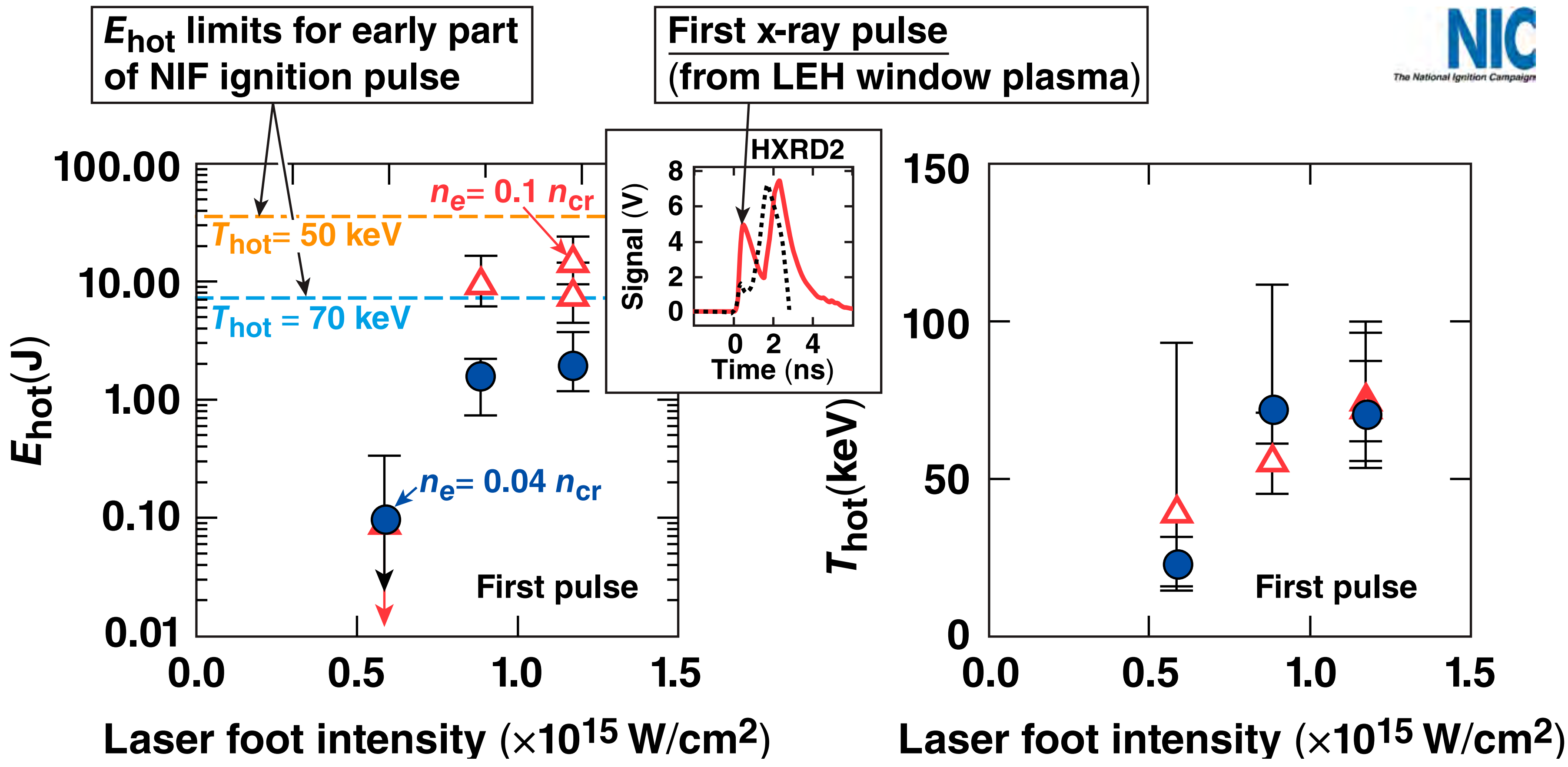
<u>NIF requirement for main drive of indirect-drive-ignition design</u>

$f_{hot} \leq 2.5\%$ for $T_{hot} = 30$ keV

f_{hot} and T_{hot} during the main drive meets the NIF requirements

E16300

Intensity-scaling experiments show a very sharp threshold for window hot electrons



E_{hot} and T_{hot} drop rapidly below this threshold

The overlapped laser intensity that burns through the window of a NIF ignition hohlraum will be designed based upon these results.

E16302

f_{hot} and T_{hot} for the second x-ray pulse are reduced with a mid-*Z* dopant in the gas fill (n_e = 0.1 n_{cr})*

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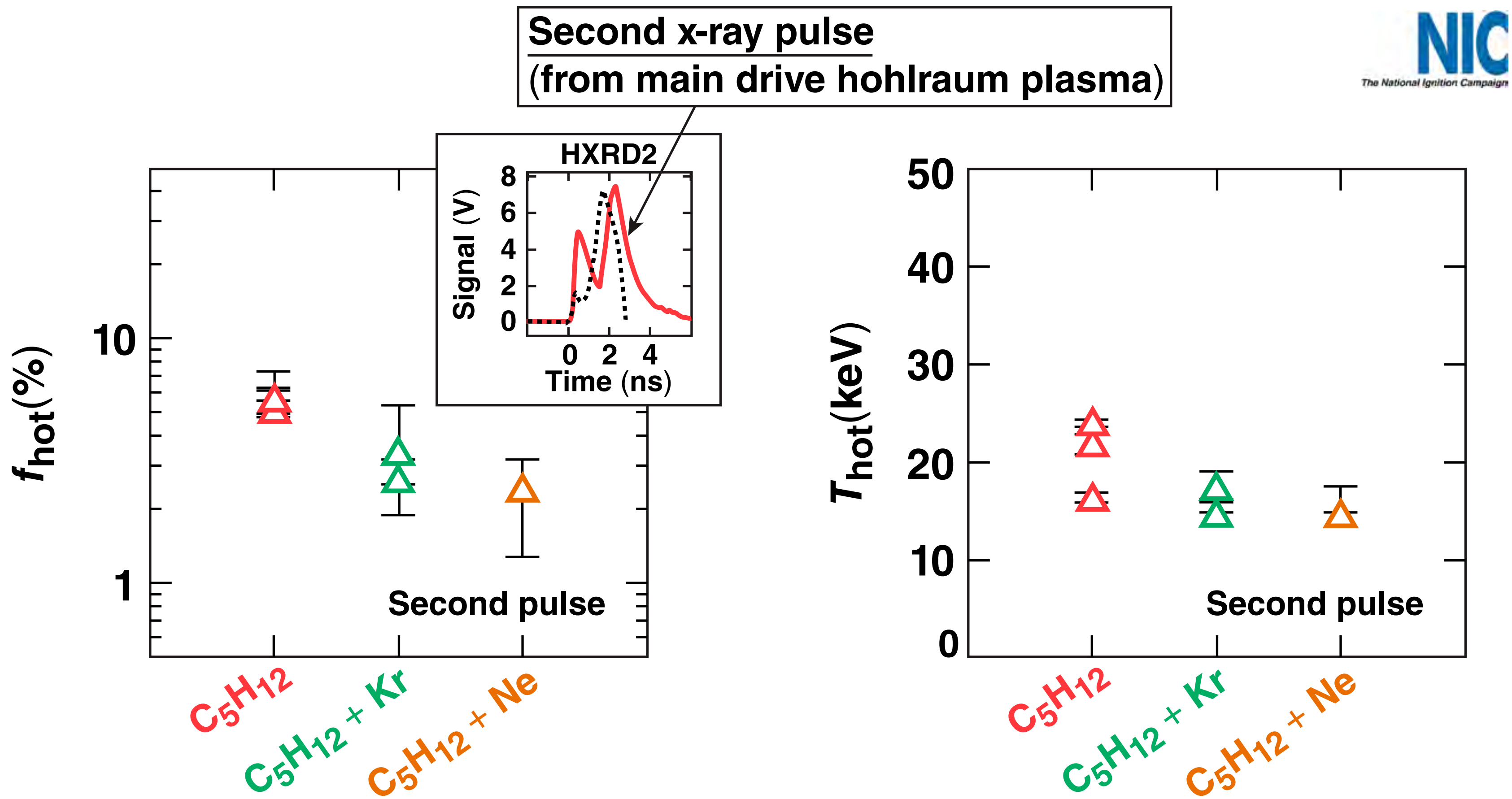
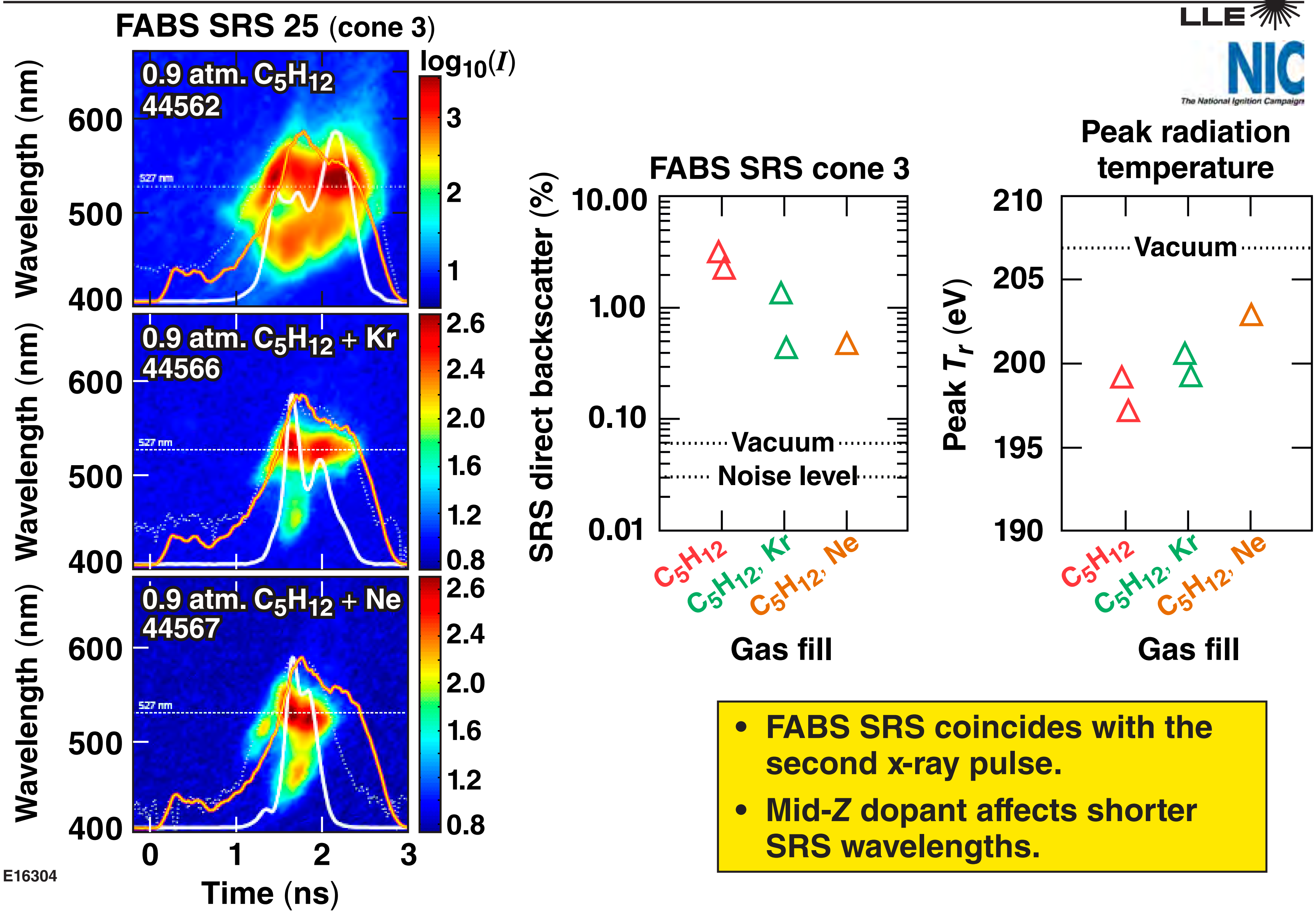


The first pulse is not sensitive to the mid-Z dopant

E16303

*R. M. Stevenson *et al.*, Phys. Plasmas 11, 2709 (2004).

The mid-Z dopant reduces SRS and increases laser-to-x-ray drive-coupling efficiency



- FABS SRS coincides with the second x-ray pulse.
- Mid-Z dopant affects shorter SRS wavelengths.

E16304

Summary/Conclusions

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<u>NIC experiments → hot-electron preheat of NIF ignition target</u>

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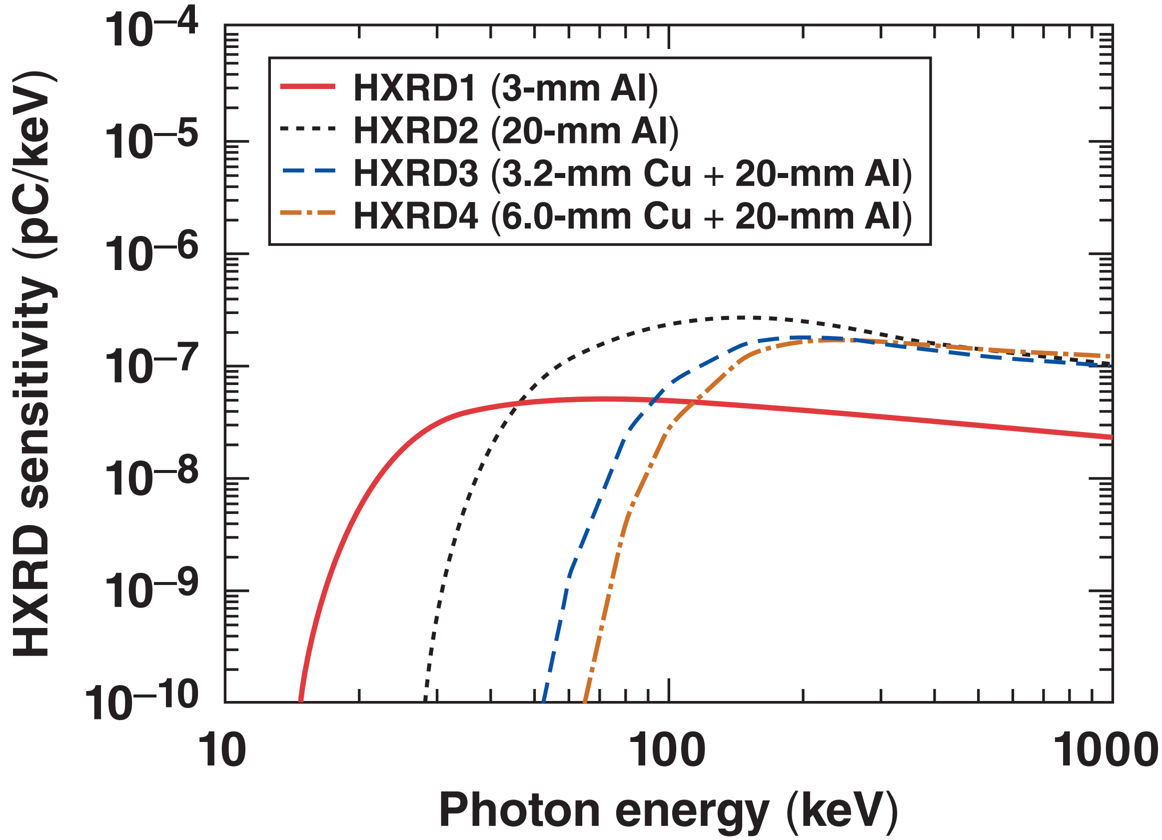
*see 2-D simulations in next talk, N. B. Meezan (NO6.00005).

The hard-x-ray diagnostic (HXRD)* is a filtered array of scintillator detectors with four energy channels



Relative calibration → filter transmission × scintillator absorption
Absolute calibration → vacuum hohlraum shot (f_{hot} ~ 1%, T_{hot} ~ 30 keV)

*C. Stoeckl *et al*., Rev. Sci. Instrum. 72, 1197 (2001).

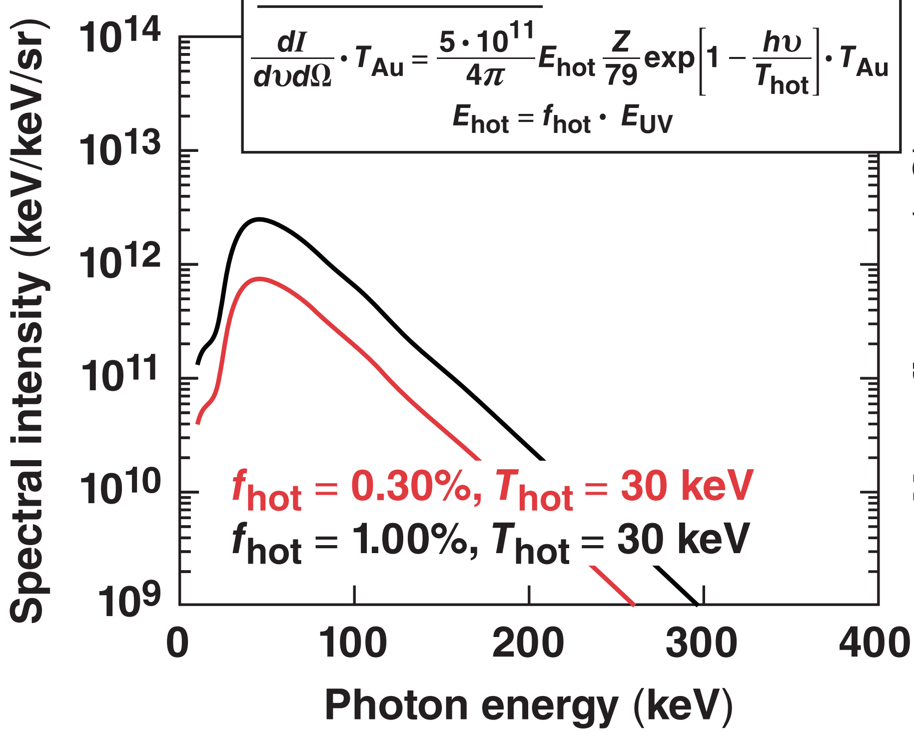
A scale-1, vacuum, Au hohlraum driven with an 18.5-kJ, 1-ns square laser drive provided an absolute calibration standard

- A similar target on Nova generated f_{hot} = 0.3% to 1% and T_{hot} = 30 keV.*

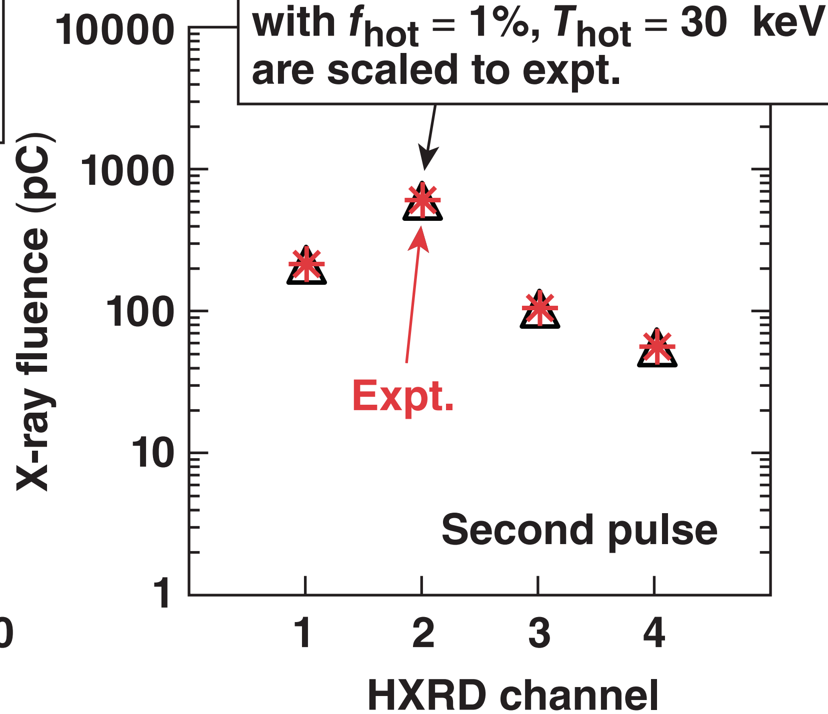
Kruer's formula:

$$\frac{dI}{d\upsilon d\Omega} \cdot T_{Au} = \frac{5 \cdot 10^{11}}{4\pi} E_{hot} \frac{Z}{79} \exp\left[1 - \frac{h\upsilon}{T_{hot}}\right] \cdot T_{Au}$$

$$E_{hot} = f_{hot} \cdot E_{UV}$$



Predicted HXRD signals with f_{hot} = 1%, T_{hot} = 30 keV are scaled to expt.



f_{hot} and T_{hot} can be estimated from HXRD signals

E16299

*R. L. Kauffman, LLNL, Nova experiment (1991).

T_{hot} and f_{hot} are inferred from the HXRD signals using a least squares fitting routine

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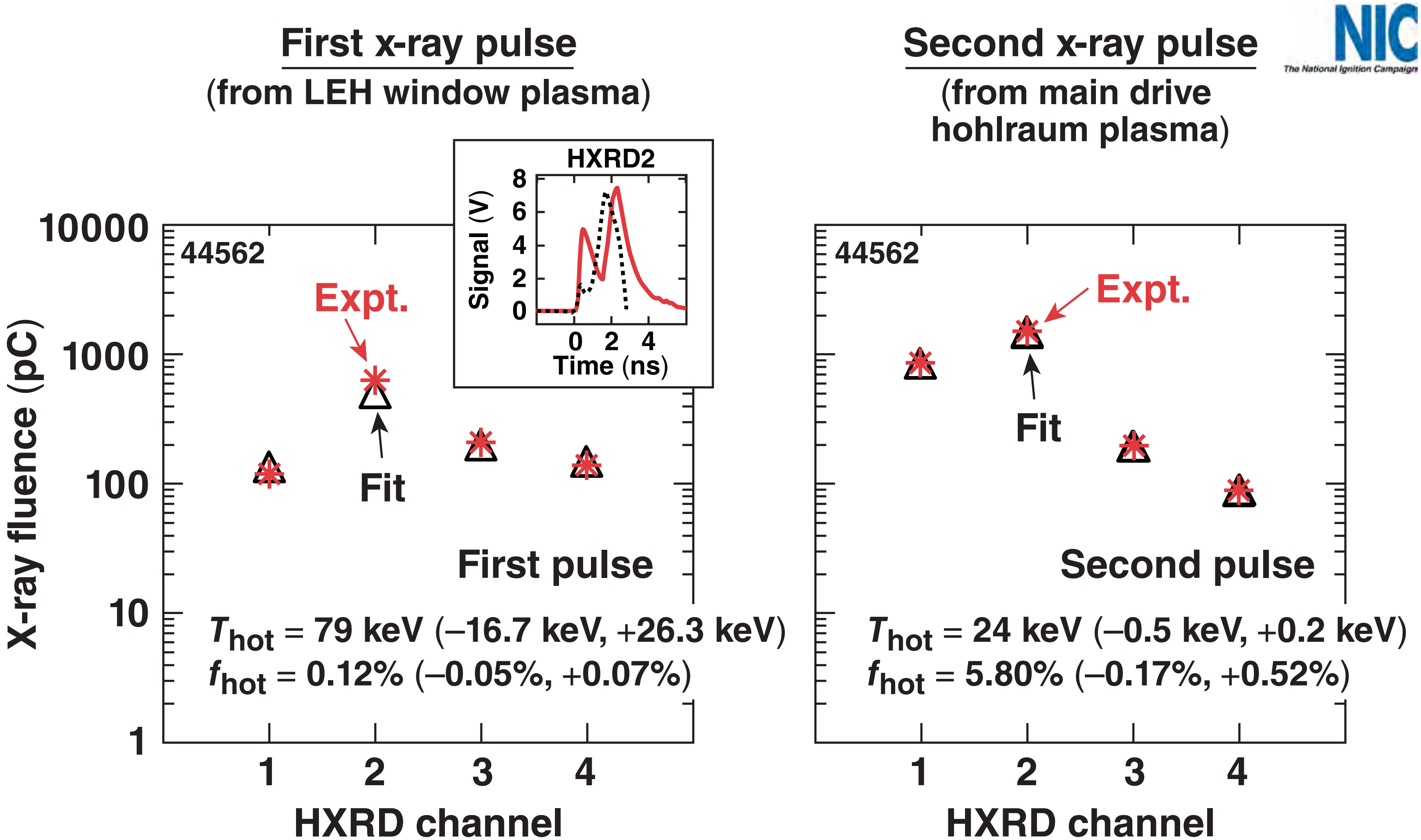

HXRD signals are sensitive to changes in f_{hot} and T_{hot}

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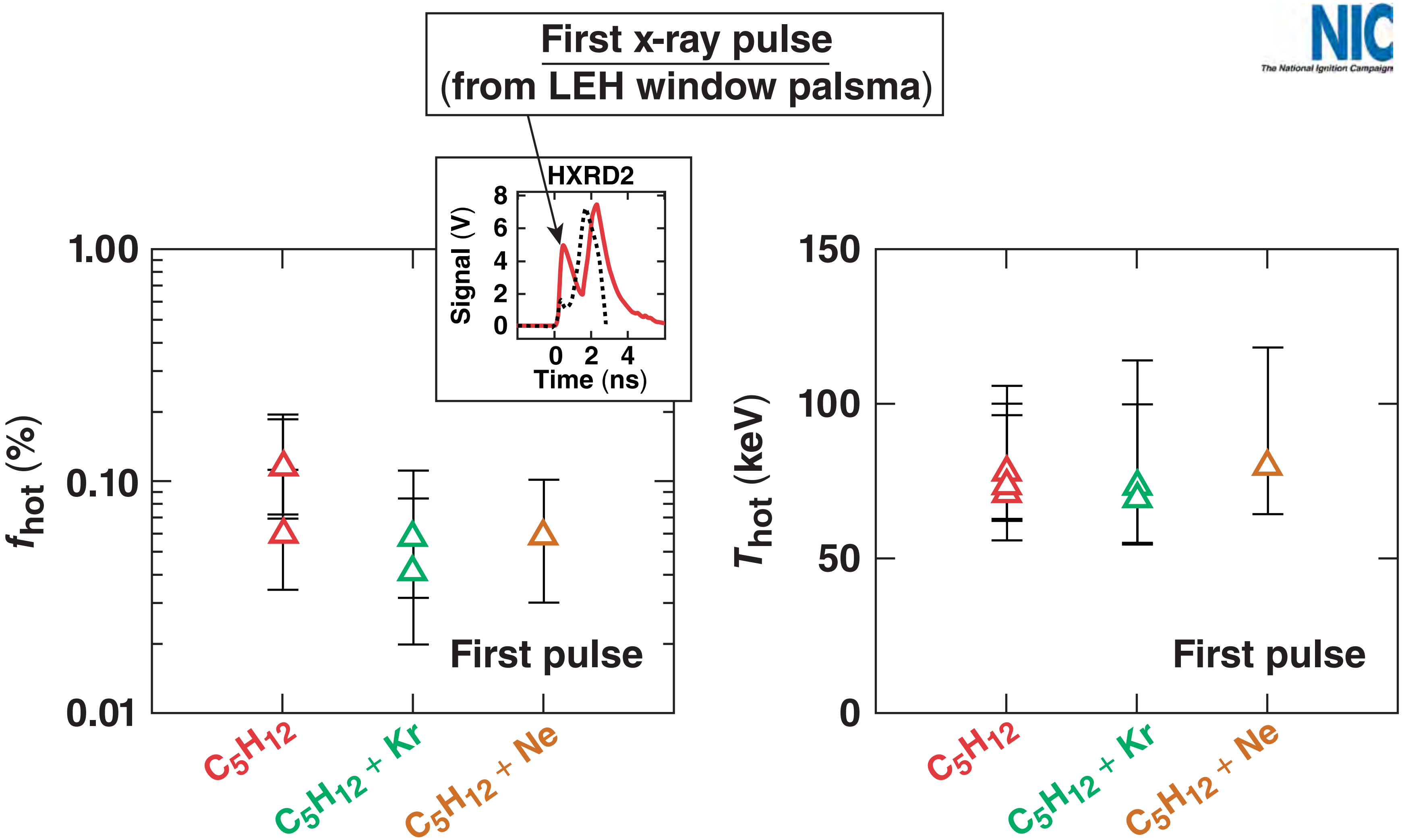
f_{hot} and T_{hot} for the first x-ray pulse are not sensitive to a mid-Z dopant in the gas fill (n_e = 0.1 n_{cr})*



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*R. M. Stevenson *et al.*, Phys. Plasmas 11, 2709 (2004).